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BIRDSFOOT TREFOIL IN MINNESOTA

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Origin and History

According to early agricultural writers, birdsfoot trefoil (Lotus corniculatus L.) has been present in grazing regions of Europe, Asia, and North Africa for many years. In the United States, it was first observed in two widely separated places--western Oregon and eastern New York. It was found growing naturally in eastern New York in the early 1930's and has since become increasingly prominent in the agriculture there. MacDonald[2] records the theory that initial introductions could have spread from ship ballast dumped along the Atlantic coast and the Hudson River.

Professor D. B. Johnstone-Wallace, Pasture Specialist for New York State Agricultural College (Cornell), observed trefoil in several New York counties. Dr. Grover F. Brown, Regional Agronomist for the Soil Conservation Service in the 1930's, encouraged additional work with trefoil by having the Conservation Corps Camp boys at Schoharie, N. Y., harvest a small amount of seed by hand. In cooperation with Professor Johnstone-Wallace and Cornell University, the Soil Conservation Service made seedings on the land-utilization project area at Turkey Hill, near Ithaca, N. Y. Farmers were encouraged to harvest trefoil seed from their wild fields.

Observational plantings were made with seed from these initial sources, which, together with imported seed from Europe, also supplied the seed for a limited number of trial plantings in almost all central Midwestern and Northern States as well. It was from such an initial planting made at the Winona, Minn., Soil Conservation Service nursery in 1938, that trefoil's persistence and increasing vigor were noted. Additional seed was obtained in 1941 from eastern New York growers and new observational trials were established on farms in Minnesota.

Plant Description

Birdsfoot trefoil has the appearance of a fine-stemmed alfalfa. Like alfalfa, the mature plant has many stems growing from a single crown. These stems grow from 20 to 40 inches in length and are fine, weak, and decumbent. Individual, widely spaced plants often spread over an area of 3 to 4 feet in diameter.

The fine leaflets grow in groups of 5, a terminal and 2 opposite lateral leaflets situated at the apex of the leaf petiole and 2 opposite sessile leaflets at its base.

Flowers are bright yellow, of the sweetpea (or legume) type, and grow in clusters of 4 to 8 at the end of the flower stalk. Each flower, when fertilized, develops a seed pod about an inch long and up to one-eighth inch in diameter (fig. 1). The pods are attached at a single point on the flower stem. As they spread they give the appearance of an inverted foot of a bird; hence the common name, birdsfoot trefoil. Each pod contains several olive green to dark brown seeds. As the pods mature, they split into halves which twist and scatter their seeds. The seeds are smaller than those of redclover and slightly larger than alsike seeds.

Birdsfoot trefoil has a many-branched taproot that resembles the redclover taproot but goes much deeper (fig. 2). MacDonald compared the root systems of redclover, birdsfoot trefoil, and alfalfa at 17 months after seeding at the Cornell station. The depth of penetration was found to average 22, 46, and 60 inches, respectively, with a corresponding lateral spread of 11, 23, and 16 inches.

Observations in Minnesota indicated that a large part of the feeding roots lies in the upper 18-inch layer of soil and that the primary branch roots are rather fleshy. The seedling plant appears to have a high proportion of root to top, which may help it to survive under ad-

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[1] Prepared from observations conducted in cooperation with H. L. Thomas and A. R. Schmid, Minnesota Agricultural Experiment Station.

[2] MacDonald, H. A. Birdsfoot Trefoil (Lotus corniculatus L.) - Its Characteristics and Potentialities as a Forage Legume. Cornell Agr. Expt. Sta. Memoir 261. 1946.

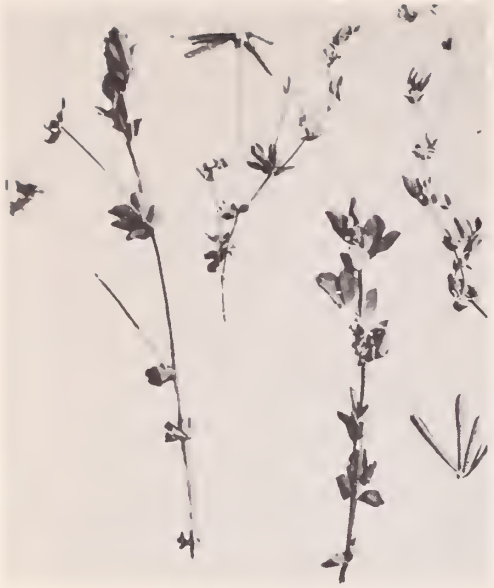

Figure 1.—A stem of a birdsfoot-trefoil plant showing leaves, blossoms, and seed pods.

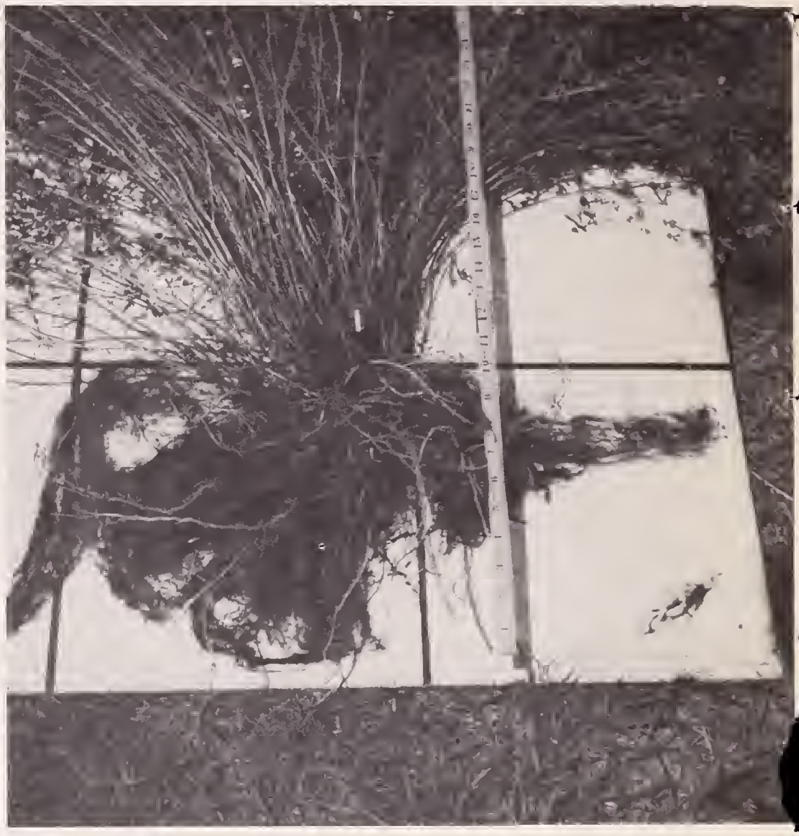

Figure 2.—A 4-year-old plant of birdsfoot trefoil showing the spreading root system with branching tap roots as well as the many fine stems which come from a single crown.

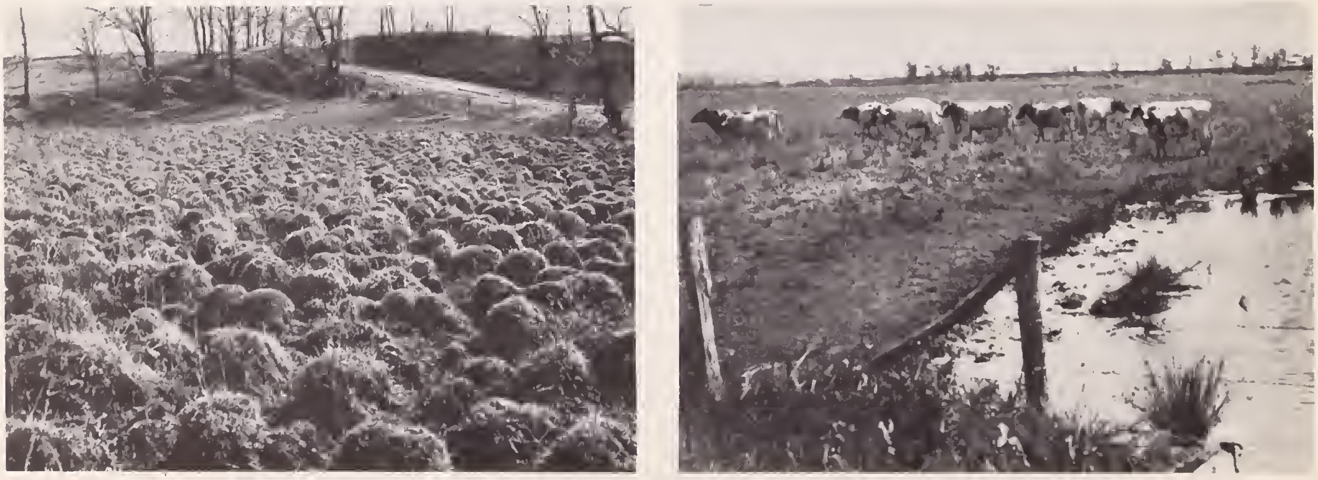

Figure 3.—Trefoil grown on a wide range of soil types including wet poorly drained subsoils unsuited to alfalfa production.

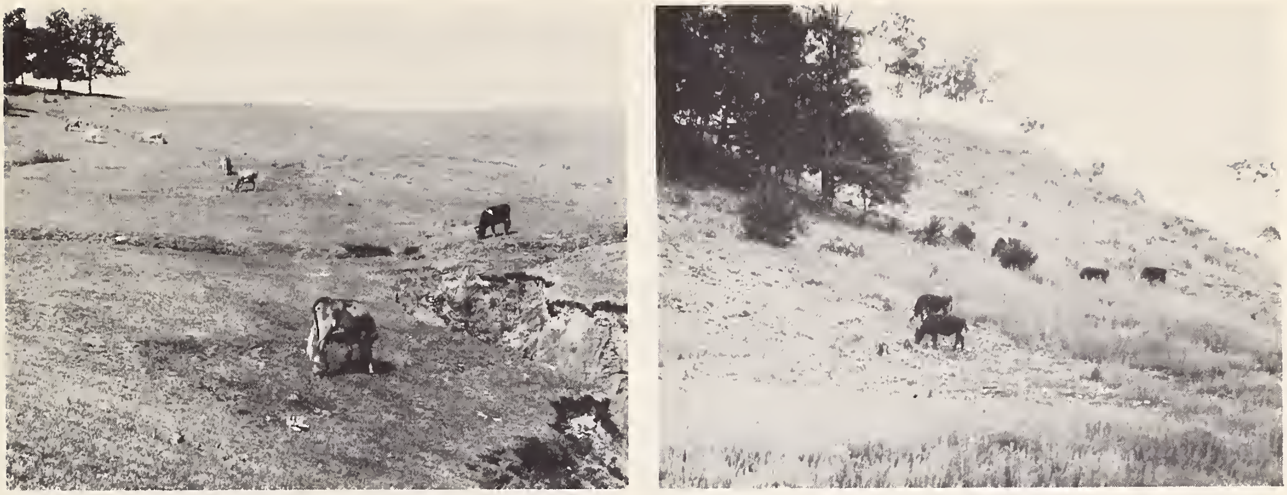

Figure 4.—Birdsfoot trefoil can be used to advantage on well-drained upland permanent pastures which are eroded, rocky, or have slopes too irregular or too steep for general cropping.

verse growing conditions. Its fine, leafy stems furnish high-quality feed over a longer season than the common legumes, because the trefoil foliage does not appear to mature as seed is formed. Hay harvest and pasturing may thus take place over a longer period of time with less sacrifice of forage quality as the plant matures.

Adaptation

Empire and related strains of broadleaf trefoil from New York have been winter hardy and produced good quality forage and seed throughout Minnesota during a 10-year period of testing. Trefoil grows on a wide range of soil types--from droughty to wet, with poorly drained subsoils, and on land unsuited to alfalfa production (fig. 3). It persists in permanent sods under conditions that are adverse to general cropping practices.

Trefoil maintains itself on soils of low fertility but responds to fertilizers, especially phosphorous. In Minnesota, both the vigor of the stand and the production improved where 0-20-0 and 0-20-20 fertilizers were used. Once established, trefoil tends to produce well on fertile soils that are low in calcium. Where acidity or low fertility of the soil is the limiting factor, the use of lime and fertilizer is recommended on soils which normally give a low-crop return. On productive soils, trefoil responds to fertilizer less quickly than common clovers and alfalfa. Trefoil tends to be less vigorous when grown with other legumes for hay.

General Uses

The best use of birdsfoot trefoil in Minnesota is to provide a perennial legume for permanent pastures (fig. 4). It replaces none of the common clovers or alfalfa. Instead, it supplements the other legumes by filling a need for a high-quality long-lasting legume for permanent pasturelands that are not suited to general farming. Because of its permanent nature and the high initial cost of seed, trefoil is not recommended in short crop rotations. On good cropland, the common clovers and alfalfa will produce more total feed than trefoil during the first 2 years after seeding.

Trefoil also makes good hay and silage. Once it is established, its production can help the farmer fill his requirements for a continuous supply of high-quality forages.

It is also one of the legumes that can easily be worked by the common honeybee; with its colorful blossoms and low-growing foliage, it is a welcome addition to the bee pastures on wastelands, new road cuts, and drainage ditchbanks, and in ornamental plantings.

Observations from a number of sources, including Minnesota, indicate that the plant has the following advantages and weaknesses:

Advantages--Trefoil is a deep-rooted, winter-hardy perennial legume. It is heat and drought resistant and grows under a wide range of soil, acidity, and fertility conditions. It is a heavy producer of both seed and high-quality forage that remains leafy, does not become woody, and remains palatable to livestock throughout the entire grazing season. It grows well with bluegrass and other sod-forming grasses and survives even under severe grazing abuses. No cases of bloat from trefoil have been reported.

Weaknesses--Trefoil usually is not high producing during the first year. It starts slowly in the spring and recovers slowly after seed and hay harvest. The initial seed cost is high, and the harvesting of seed is often difficult.

Varieties and Types

The cultivated birdsfoot trefoils used for forage in the United States are divided into two species or common groups: Lotus corniculatus (broadleaf trefoil) and L. tenuis (narrowleaf trefoil).

TABLE 1--Growth, flowering, seed setting, stand, and recovery data for various strains of birdsfoot trefoil at two locations in Minnesota, 1949-52.

Strains	May 17, 1950	June 6, 1950				Average of 2 farms						
						Oct. 12, 1950	May 15, 1951		Oct. 15, 1951	May 20, 1952		
	Height of new growth	Height	Bloom	Seed-pod set	Stand	Stand	Height	Stand	Stand	Height	Stand	Winter injury
	Inches	*Inches*	*Percent*	*Percent*	*Percent*	*Percent*	*Inches*	*Percent*	*Percent*	*Inches*	*Percent*	*Percent*
NEW YORK BROADLEAF												
NY F.C. 23218	1.3	18	40	0	95	86	4.0	76	91	5.5	73	Trace
NY F.C. 23416	1.0	18	37	0	98	83	4.0	78	92	6.0	58	do
NY F.C. 23417	1.6	19	28	Trace	95	86	4.0	83	92	7.0	67	do
Winona M4-19339[1]	2.0	18	37	do	97	89	5.0	77	93	6.5	71	0
Iowa M4-19908[2]	1.6	21	63	5	100	87	5.5	76	95	7.0	71	0
Moorhead M4-19909[1]	1.3	19	28	0	100	85	4.0	82	93	6.5	67	Trace
EUROPEAN BROADLEAF												
Europe F.C. 23139[3]	3.0	17	16	80	85	64	7.5	67	74	10.5	60	5
Italian F.C. 23204	2.3	14	Trace	56	73	75	6.5	79	85	9.0	68	7
Italian F.C. 23424	2.6	15	16	66	77	71	8.0	75	82	11.0	58	6
Europe F.C. 23430[3]	2.3	15	18	55	72	75	8.5	82	84	11.0	65	3
N-K Ital. M4-19895	2.6	15	Trace	82	93	86	7.5	82	76	10.5	75	9
NARROWLEAF												
Oregon F.C. 23230	1.3	3	Trace	0	58	77	2.0	21	38	2.0	7	43
Oregon F.C. 23429	1.3	3	do	0	61	75	2.0	23	48	2.0	6	37

Plots were seeded spring 1949. Soil Conservation Service and Minn. Agr. Expt. Sta. cooperating. Three replications each location. All plots had good uniform stands, free of weeds, and plants were well developed in fall 1949.

[1] Seed source materials grown in Minnesota for 10 years.
[2] Seed obtained from an old seed source in Iowa.
[3] Country in Europe where seed originated is not known.

Present day strains that are available for distribution have been produced from selections made in New York, Oregon, and Washington and European strains imported from France and Italy. Plantings from different seed sources indicate considerable variation in plant types. Uniform nursery plantings, and comparative plantings under farm conditions, have been made in Minnesota. As a group, the imported broadleaf strains tend to be more erect and to blossom earlier than Empire, which is a named variety coming from eastern New York State. The imported strains, however, have been less winter hardy, and the annual forage yield has been about a ton less per acre at Rosemount and Moorhead, Minn. Winterkilling did not completely destroy stands of clipped European broadleaf types in 1950, 1951, or 1952, but the stands did show extensive injury. Therefore, it is felt that these types would have winterkilled completely under more severe treatment, such as pasturing. Data on growth, flowering, seed setting, stand, and recovery for 13 accessions of birdsfoot trefoil tested at 2 locations are given in table 1.

The Oregon narrowleaf plantings were severely damaged by winterkilling each year, but were able to reseed themselves sufficiently to make a fair yield by second-crop hay-cutting time.

Farmer experience in Minnesota and experiments at the agricultural experiment station with the imported strains have given poor results due to winterkilling and a general failure of the stands to survive more than 1 to 2 years. Field seedings made by the Soil Conservation Service have been with seed of the broadleaf type. The Empire strain from New York is recommended for Minnesota. The imported types yielded less and their longevity is questionable, because as a group they appear to be more susceptible to disease such as crown rot.

Other varieties recently released by other States, but not completely tested in Minnesota, are:

Cascade, a new broadleaf strain that was selected from European broadleaf by the Soil Conservation Service and the Washington Agricultural Experiment Station:

Viking, a broadleaf strain that was selected from European stocks by the Cornell Agricultural Experiment Station in New York; and

Granger, a broadleaf strain of European origin that was selected and increased for release by the Oregon Agricultural Experiment Station and the Bureau of Plant Industry, Soils, and Agricultural Engineering.

In addition to birdsfoot trefoil, two varieties of Lotus uliginosus (big trefoil) were also included in the observational plantings in Minnesota. The plants completely winterkilled the first year at all sites.

Seeding Rates and Mixtures

Four to five pounds of clean birdsfoot trefoil seed per acre are considered ample for seeding permanent pastures. No additional grass seed is needed on renovated bluegrass. Seedings on clean-tilled land should include 4 to 6 pounds of timothy, bromegrass, or other tame grass seed to provide a good grass cover. Forage production can be increased the first year, if desired, by seeding 3 to 4 pounds of redclover or sweetclover per acre, but this practice reduces the trefoil stand unless the field is grazed heavily the first year. Volunteer clovers and grasses should be grazed. Cutting for hay reduces the proportion of trefoil in mixed seedings, especially on soils that are fertile enough to grow a vigorous sod but trefoil competes with the common clovers when growing on sites of low fertility.

From 30 to 50 percent of the birdsfoot trefoil seed crop is hard seed. Consequently, stands thicken after the first year from the germination of both the hard seeds and the seed produced by new plants.

Early spring seeding is preferred, since it gives the seedlings time to become established before the adverse growing conditions of dry or cold weather set in. Rough seedbeds will produce satisfactory stands in areas of moist, rainy spring weather but in droughty seasons or on droughty sites the seed must be drilled into a firm, moist seedbed at a shallow depth of from one-fourth to one-half inch in order to get satisfactory stands.

Any cultural treatment which permits the seed to maintain a contact with moist soil at a shallow depth will aid in the establishment of trefoil. This condition must be maintained long enough to allow the root to become established. Schmid[3] reports that such a condition is obtained by cultipacking the seedbed, shallow drilling of the seed, and then a second cultipacking operation. Observations in Minnesota show that stands of trefoil were better where the new seedings were grazed than where they were clipped or left to grow undisturbed. July and August seedings on prepared seedbeds have been successful where moisture and fertility can be controlled.

Inoculation

Birdsfoot trefoil requires its own strain of bacteria, which are uncommon in fields where trefoil has not been grown previously. It is very important to establish desirable strains of bacteria on new plants as early as possible. This is especially true when seedings are being made on sites that may be poorly drained, low in fertility, eroded, or droughty. Commercial cultures of beneficial bacteria are readily available from producers of inoculant material.

The directions given on the container for using the inoculant should be followed carefully, and the seed planted within 48 hours after being inoculated. The use of a small amount of sugar syrup to hold the inoculant on the seed

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[3] Schmid, A. R. and Rud, O. E. Seeding methods and your crops. Minn. Farm and Home Sci. Vol. IX. No. 2. Feb. 1952

TABLE 2--Percents and yields of protein with percent legumes on pasture-renovation plots in southeastern Minnesota, 1948-52. Averages are based on from 2 to 4 cuttings per year per farm.

Location	Treatment	Crude protein								4-yr ave.	Average percent legumes				
		1949		1950		1951		1952							
		Per-cent	*Lbs/ac.*	*Per-cent*	*Lbs/ac.*	*Per-cent*	*Lbs/ac.*	*Per-cent*	*Lbs/ac.*	*Lbs/ac.*	*'48*	*'49*	*50*	*'51*	*'52*
Hink-------	Bluegrass	11.3	45	14.0	172	16.87	612	13.59	446	294	0	0	25	66	53
Schell-----		17.0	381	15.5	321	16.74	569	15.73	635	477	0	0	9	38	17
Wacholz----		15.4	210	16.5	373	16.52	714	13.62	398	424	2	0	18	37	21
Treveer----		14.2	106	13.5	130	15.10	480	12.65	373	272	--	--	4	25	10
	Average	14.7	186	14.9	249	16.3	569	13.89	463	367	1	0	14	42	25
Hink-------	Birdsfoot trefoil and grass	17.2	427	14.6	468	16.57	889	15.50	844	657	60	65	49	67	79
Schell-----		15.6	667	16.2	702	16.09	903	14.95	749	755	63	72	68	76	75
Wacholz----		17.8	894	17.4	793	19.06	1,220	15.78	724	908	50	67	72	80	77
Treveer----		14.9	373	16.5	613	18.64	1,182	14.85	859	757	--	20	56	69	66
	Average	16.4	590	16.2	644	17.71	1,048	15.27	794	769	58	56	61	73	74
Hink-------	Ladino-grass	10.3	74	--	--	--	--	--	--	--	27	0	--	--	--
Schell-----		12.8	326	--	--	--	--	--	--	--	12	0	--	--	--
Wacholz----		13.8	202	--	--	--	--	--	--	--	10	0	--	--	--
Treveer----		17.0	586	16.9	683	19.49	1,255	14.95	810	834	--	50	44	80	58
	Average	13.5	298								16	12			
Wacholz----	Alfalfa-brome	16.2	919	15.9	1,054	14.52	859	12.92	528	840	8	70	50	52	48
Treveer----		19.8	1,037	17.2	1,010	18.10	1,130	13.12	777	989	--	85	74	62	29
	Average	18.0	978	16.5	1,032	16.31	994	13.02	652	914	8	78	62	57	39
Treveer----	Sweetclover	19.7	796	14.9	543	16.31	1,063	12.71	622	756	--	100	16	46	17

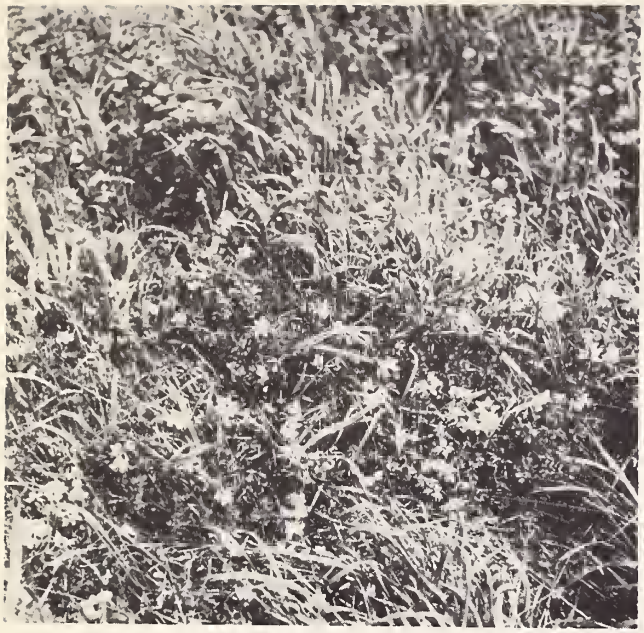

Figure 5.–Stands increase after the first year and trefoil maintains itself at about 50 percent of the mixtures of forage when growing with bluegrass in permanent pastures.

has been suggested as a help in establishing beneficial bacteria.

Anything which helps disseminate the beneficial inoculant to new plants, such as pasturing, dragging, or tilling, can speed up the complete inoculation in a field. Old trefoil fields that are renovated or reseeded to trefoil are more easily and uniformly inoculated and produce better during the first year than most fields that are seeded to trefoil for the first time.

Use as Pasture

Birdsfoot trefoil is primarily a permanent-pasture legume, capable of producing a good yield of high-quality forage on land not adapted to alfalfa and clover, or on land which is unsuitable for normal crop production. Although its yields may be low the first year, stands and production increase in the succeeding years (fig. 5). It maintains itself at about 50 percent of the total forage when growing with bluegrass in permanent pasture. The early spring growth in permanent-pasture mixtures usually has more grass, but the midsummer growth shows more trefoil. Because of trefoil's low-growing habits, livestock cannot eat all the stems. This permits the plants to produce some seed each year and be persistent even under intense overgrazing conditions. Plantings made in 1942 in permanent pastures in Minnesota, which have been grazed with both cattle and sheep, have been productive. Birdsfoot trefoil has spread and improved its stand. Other legumes planted in the same pasture have disappeared, except for an occasional plant of volunteer clover. The persistence of birdsfoot trefoil, combined with good management practices and topdressing of fertilizer, will do much to maintain production on permanent-bluegrass pastures during July and August. Trefoil is capable of surviving more overgrazing and mismanagement than other common legumes. Bloat has never been reported by any of the few farmers in Minnesota who have trefoil pastures of 10 acres or more.

Table 2 shows that legumes, except alfalfa, made up a larger part of the vegetation each succeeding year in the pastures studied. The increase in legumes was largely due to a heavy snow cover in the winter of 1950-51, followed by a moist growing season which encouraged volunteer wild whiteclovers. The stand of trefoil, however, was persistent even in the dry years of 1948 and 1949. As also shown in table 2, the percentage of trefoil on the Treveer farm, starting at 20 percent of the stand in 1949 and increasing to 56 percent, 69 percent, and 66 percent in succeeding years is representative. Protein percentages and yields per acre show alfalfa to be the best of the legumes tested under these soil conditions. When the comparison is made on the same farm between the 2 crops, the difference between alfalfa and trefoil is not so great. On all the farms, the improved pastures with added legumes far outyielded the bluegrass pasture in crude protein and forage per acre (tables 2 and 3). The increased percentage of legumes raised the protein yield even in the bluegrass-check pasture.

Use for Hay

Birdsfoot-trefoil hay of good quality can be made with ordinary farm machinery although the weak stems make a matted growth which is hard to cut clean. Grass mixtures make the trefoil plants easier to mow if they hold the growth up off the ground. Trefoil is suitable for permanent hayfields, or sites which require permanent cover that might be used for either hay or pasture.

Trefoil has a tendency to maintain itself in bluegrass sods and gives a consistent yield longer than alfalfa. It should normally be expected to give 2 good cuttings per season in Minnesota, for a total yield of 2 to 3 tons per acre. Yields on a variety test at Rosemount in 1951, when moist weather encouraged vegetative growth, produced 3 to 4 tons of hay, with a moisture content of 15 percent, in 2 cuttings. At the same moisture content, the New York broadleaf strains averaged 4.28 tons of hay per acre, while the European broadleaf strains averaged 3.16 tons, and the Oregon narrowleaf strains averaged 1.64 tons. The low yield of the first cutting on the narrowleaf strains was caused by the severe winterkilling under Minnesota conditions (table 4).

Birdsfoot trefoil reaches the hay-cutting stage of half to full blossom in Minnesota during the latter part of June and is ready for a second cutting in August. Northern Minnesota may get only one good cutting, with a fair aftermath for grazing, however. A long delay in taking the first cutting or taking seed on the first crop will reduce the yield of the second crop.

TABLE 3--Yields from renovated pasture in southeastern Minnesota, 1948-52.[1] Pastures seeded 1946.[2]

Location	Treatment	1948	1949	1950	1951	1952	5-yr ave.
			Tons per acre				
Hink	Bluegrass	0.82	0.26	0.74	2.17	1.93	1.18
Schell[3]		1.46	1.34	1.24	--	2.41	[4] 1.61
Wacholz[5]		1.00	.84	1.36	2.53	1.70	1.48
Treveer		--	.39	.56	1.83	1.78	[4] 1.14
Average		1.09	.71	.98	2.18	1.95	1.35
Hink	Birdsfoot trefoil and grass	3.03	1.51	1.60	3.22	3.20	2.51
Schell		2.54	2.52	2.67	3.25	3.03	2.80
Wacholz		2.26	2.62	2.79	3.57	2.78	2.80
Treveer		--	1.42	2.17	3.74	3.39	[4] 2.68
Average		2.61	2.02	2.31	3.45	3.10	2.70
Hink	Ladino and grass	1.46	.45	--	--	--	[6] .96
Schell		1.57	1.52	--	--	--	[6] 1.55
Wacholz		1.81	.88	--	--	--	[6] 1.35
Treveer		--	1.90	2.40	3.74	3.19	[4] 2.81
Average		1.61	1.19				
Wacholz	Alfalfa and brome	1.22	3.39	3.84	3.44	2.40	2.86
Treveer		--	3.09	3.61	3.65	3.51	[4] 3.47
Average		1.22	3.24	3.72	3.55	2.95	3.16
Treveer	Sweetclover	--	2.47	2.21	3.56	2.91	[4] 2.79

[1] 15-percent moisture.

[2] Data collected by E. L. McPherron, Soil Conservation Service, in cooperation with Minnesota Agricultural Experiment Station.

[3] 100 lb. ammonium nitrate in spring 1949.

[4] 4-year average.

[5] Topdressed with 8 tons manure per acre in spring 1949.

[6] 2-year average.

Soil Improvement

As a green-manure crop for plowing down in a short crop rotation, trefoil is unsuitable because of low yields the first year. It is more useful as a legume for hazardous cropping conditions and unfavorable soil sites. It can help improve the soil by its ability to persist under adverse conditions, but it should be grown with a grass to provide adequate erosion control. The wide-branching root system, combined with a stable winter cover of dead aftermath, makes it a good mulching plant on raw sites. There are thousands of acres of noncropland used for grazing where trefoil can increase production and improve the quality of the forage.

Seed Production

Empire birdsfoot trefoil has an indeterminate type of blossoming, which gives rise to green, succulent plants with blossoms and green and ripe seed pods on the same plant for a considerable length of time during the growing season. It will produce seed each year. Harvesting of the seed must be done at just the right time--when the bulk of the seed pods are turning brown and before excessive loss of seed by shattering has occurred--in order to get a good seed yield.

Birdsfoot-trefoil flowers are highly self-sterile, but fertile between plants in the same species, and therefore must be cross-pollinated. The small, pealike flower is easily worked by honeybees. Wildbees and bumblebees are also found in the fields. Fifty colonies of honeybees have been kept in proximity to the 10 acres of trefoil at the nursery. It is desirable to get the fields pollinated quickly, in order to produce a good set of seed pods which will ripen at the same time. Rain and cloudiness may reduce the activity of the honeybees.

Seed can be harvested from trefoil pastures and hayfields by proper management and planning for a seed crop. Fields intended primarily for seed production, however, should be planted to trefoil alone. Although grass in the mixtures may help with the curing and handling of the crop, it is not absolutely necessary. Very heavy growths of trefoil tend to lodge even with grass, and such crops as bromegrass have tended to reduce seed yields. Seeds of volunteer clovers are hard to separate from trefoil seed.

Seed production in Sherburne and Winona Counties, Minn., has been on sandy-loam soil with a droughty subsoil (fig. 6).

The field in Sherburne County was established in the spring of 1947. Because there was very little rainfall that spring, the seedling plants which survived were poorly developed. A good stand was established in the second year from seed which did not germinate the first year, however. The field was topdressed with 200 pounds per acre of 0-20-20 fertilizer in 1948 and 1950 after the seed crops were harvested. The trefoil was mowed with a windrower attachment on a power mower and threshed with a

TABLE 4--New York broadleaf type of birdsfoot trefoil gave the highest yields at Rosemount, Minn.[1]

Species	Cut 6/27/51	Cut 8/6/51	Total
New York Broadleaf type	*T/ac.*	*T/ac.*	*T/ac.*
NY F.C. 23218 Empire----	2.27	2.08	4.35
NY F.C. 23416 Empire----	1.47	2.43	3.90
NY F.C. 23417 Empire----	2.61	2.05	4.66
Winona SCS M4-19339-----	1.96	2.02	3.98
Iowa SCS M4-19908-------	2.13	2.24	4.37
Newday Sel. Moorhead M4-19909--------------	2.26	2.15	4.41
Average 6 strains----	2.12	2.16	4.28
European broadleaf types			
Europe F.C. 23139-------	1.37	1.99	3.36
Europe F.C. 23204-------	1.18	1.60	2.78
Europe F.C. 23424-------	1.12	2.01	3.13
Europe F.C. 23430-------	1.87	2.02	3.89
Northrup-King, Italian M4-19895--------------	1.22	1.43	2.65
Average 5 strains---	1.35	1.81	3.16
Narrowleaf types			
Oregon F.C. 23230-------	.18	1.13	1.31
Oregon F.C. 23429-------	.41	1.56	1.97
Average 2 strains---	.30	1.35	1.64
L.S.D. 5 percent	.79	.87	

[1] Forage yield in 15 percent moisture 1951 from 2 replications planted in 5-row plots in spring 1949. Unpublished data taken by Dr. H. L. Thomas and D. D. Dickenson.

pickup combine. In table 5 there is shown the production of clean seed obtained without irrigation.

The hay yield was heaviest in 1951, at an estimated 3 tons per acre. Rain, and conditions too wet for threshing, prolonged the harvest period and caused excessive loss of seed by shattering.

The trefoil-seed fields at Winona have received an average annual application of 150 pounds of 0-20-20 fertilizer per acre per year. Most of the present acreage now in production was seeded in 1945. The record of clean-seed production to date at the Winona nursery is given in table 6.

Various clipping and harvesting methods have given yields of from 0 to 257 pounds of clean seed per acre. A combination of factors, such as moisture, temperature, and cloudiness, have contributed to seed production. Excessive growth of forage has made handling the seed crop difficult. A heavy bloom may not assure a high seed yield, owing to (1) extended hot, dry weather when there is not enough reserve moisture in soil, (2) poor pollination, and (3) insect injury when excessively warm, moist conditions persist under the forage during the time the seed crop is being formed.

There was a good overall yield in 1947 when the rainfall was well distributed, with about an inch per week throughout the whole growing season. This experience led to supplementing rainfall with irrigation water in 1949 and 1950, which gave very good results. In 1951, however, an excess of moisture and cloudy days almost caused a failure. Even though there were several good sets of blossoms, no pods formed. Irrigation water was applied to all fields in 1950 and, with the exception of 2 acres, they were all clipped the first week of June. The bulk of the seed harvested in 1950 came from the 2 unclipped acres, which yielded 514 pounds of clean seed for an average acre-yield of 257 pounds.

Although seed is being produced all summer, the most dependable seed crop has been obtained from the first cutting. Clipping and pasturing have tended to reduce seed yields. In 1949, 2 seed crops which averaged 60 and 50 pounds per acre were obtained from the same fields in the same year. Good rains came immediately following the first cutting to supply the moisture for the second seed crop. Small growth and thin stands have yielded good seed crops, and the forage is much easier to handle.

Harvesting Seed Crop

Seed is harvested when a majority of the seed pods have turned brown but have not shattered. At Winona, harvesting usually occurs the last week of July and the first week of August. Three methods of harvesting have been tested--combining direct, combining from partly cured windrows, and threshing from the stack.

Combining direct did not prove practical. Harvesting can be done only during the middle of the

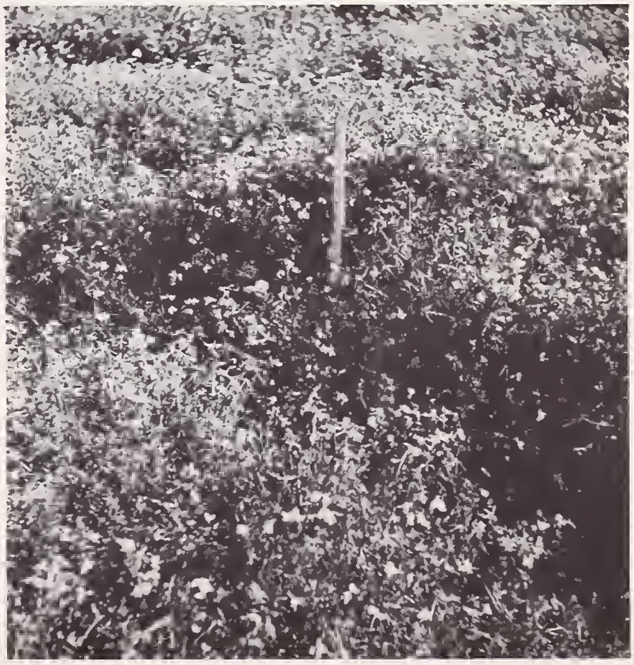

Figure 6.--Five-year-old stand of Empire for seed production growing on a sandy loam soil of Class IV and VII capabilities.

TABLE 5--Birdsfoot-trefoil seed production on 13.5 acres in Sherburne County, Minn. Fields established with eastern New York broadleaf trefoil.

Year	Lbs. clean seed per acre
1948	9
1949	74
1950	47
1951	48

TABLE 6--Birdsfoot-trefoil seed production on the Soil Conservation Service nursery at Winona, Minn. Fields established with eastern New York broadleaf trefoil.

Year	Area harvested	Ave. lbs./ac. clean seed	Annual rainfall at Winona
	Acres		*Inches*
1943	0.9	60	24.15
1944	.9	30	23.52
1945	.9	88	34.36
1946	7.5	20	27.26
1947	7.5	197	37.77
1948	7.5	11	23.97
1949[1]	3.0	150	24.97
1949[2]	7.5	51	
1949	15.0	56	
1950[3]	7.5	118	27.02
1951	10.0	60	39.99
Total	50.0	84	

[1] 3.0 acres irrigated; 4.5 acres cut for hay--no seed, first cutting.
[2] Second cutting.
[3] All irrigated.

day, even in hot, dry weather. It is necessary to separate the seed from the green material immediately after harvesting to prevent heating.

Combining from the windrow has been very successful, but it is necessary to thresh before seed pods shatter. When the weather is dry, threshing may start within 24 to 48 hours after the crop has been cut and put into the windrow. The seed and green material should be separated to prevent heating. The clean seed should be stirred occasionally so that it can dry thoroughly before storage.

Threshing seed from the stack is more costly because of labor and equipment, as compared with the other two methods. It is still necessary to clean the seed after harvesting. Although it contains no green material, there are a lot of pods, stems, and dirt. The additional handling of the material causes the seed to shatter unduly when it is stacked, as evidenced by seed on the wagon rack and canvas. It also requires extra labor and causes seed loss which cannot be avoided. This method has no advantages. Table 7 indicates the yields at Winona, Minn.

Since 1947, practically all harvesting has been from the windrow with a combine. A power mower with windrower attachment is used to cut the crop. Mowing should be done when the pods are moist, in order to reduce shattering.

Hughes[4] reports using a round baler to pick up the windrows. Later the bales are cut lengthwise and threshed. This takes added labor but may save seed if the weather is too wet for combining. This method allows the work of threshing to be done at the barn when convenient, and gives a fair quality of hay. The extra handling and the difficulty of securing additional equipment may limit its use. Regardless of how the crop is handled and the method used, some seed will be lost. A vacuum harvester was tried with little success, because the suction necessary to get the small individual seeds, drew large quantities of dirt and gravel into the machine. Separating the seed from this debris was too difficult to be practical.

Injurious Insects, Fungi, and Insecticide Recommendations

Grasshoppers, leafhoppers, Lygus sp., and other insects have been observed in trefoil-seed fields in varying populations each year. No direct studies have been made of the influence of these injurious insects on seed production. Seed production in 1951 was poor, considering all factors. Adverse weather conditions may have influenced seed production because of excessive vegetative growth and poor pollinating weather, but injurious insects such as Lygus sp., were very numerous. Several good blossom sets dropped off without forming seed.

Birdsfoot trefoil is also subject to Rhizoctonia and Sclerotina, stem and crown rots which may occur under conditions of very heavy growth and high humidity. Stands of trefoil were considerably reduced under such growth conditions at Winona, but where the stands are pastured, these diseases do very little damage.

Grasshopper control should not be difficult if fields and borders are sprayed before damage occurs.

Controlling other injurious insects without harming the pollinators is difficult. Early sprays might become ineffective if applied only once before blossoming time, since flowering takes place over a prolonged period. Close observations, selective insecticides, and night spraying are possibilities to determine the effectiveness of injurious-insect control.

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[4] Hughes, H. D. Forage Notes August 1951. Iowa State College.

TABLE 7--Birdsfoot-trefoil seed production at the Soil Conservation Service nursery, Winona, Minn., 1947.

Item	Acres	Yield-rough per ac.	Yield-cleaned per ac.	Percent Germ.	Percent Purity
		Lbs.	*Lbs.*		
Trefoil and brome[1]	2.21	219	173	79	99.4
Trefoil and redtop[1]	1.54	284	242	86	99.7
Trefoil alone[1]	1.36	255	187	73	99.4
Trefoil alone[2]	2.39	161	134	83	99.6
Total	7.5	221	177	80	99.5

[1] Windrow combined.
[2] Stacked July 1947, threshed Sept. 1947.

Summary and Conclusions

Birdsfoot trefoil has been under observation in Minnesota since 1938, when initial plantings were made by the Soil Conservation Service from seed obtained in New York State.

Birdsfoot-trefoil seed from New York State, West Coast States, and Europe has been used in varying quantities for both commercial and observational plantings.

The plant is a fine-stemmed perennial legume that shows persistence and drought resistance. It has a many-branched taproot that penetrates the soil to a depth intermediate between the depth of penetration by alfalfa and redclover taproots.

The Empire variety of birdsfoot trefoil has been winter hardy in Minnesota on a wide range of soil types, from droughty to wet, with poorly drained subsoils, and on land unsuited to alfalfa production.

The crop is best suited in Minnesota for use as a perennial legume for permanent pastures.

Trefoil tends to produce well on soils low in lime. It responds to applications of phosphorous. The use of lime and fertilizer is recommended on soils which normally give a low-crop return.

New York strains of broadleaf trefoil, such as Empire, are recommended for Minnesota in preference to imported strains or narrowleaf strains.

Four to five pounds of clean seed per acre are considered ample for seeding on permanent pastures.

Seed should be planted in the spring at a shallow depth of one-fourth to one-half inch in a seedbed which favors development of legume seedlings. Grazing the first year favors the development of trefoil.

Inoculation of trefoil with its own strain of bacteria is essential to a successful seeding.

The fine stems and leaves of an established field of trefoil makes good quality forage when used either as hay or pasture.

Slowness to reach maximum production and the relatively high initial seed cost make trefoil a poor crop for use in short crop rotations or as a green manure.

Trefoil does not lose its succulence as quickly as alfalfa when it approaches maturity. This fact makes it possible to harvest good quality trefoil forage over a longer period.

Birdsfoot trefoil is primarily a legume for use in permanent sods and is capable of maintaining good stands and yields of high-quality forage on land not adapted to alfalfa and clover, or on land which is unsuitable for normal corp production.

Trefoil will produce seed each year, but its indeterminate growth results in blossoms and green to ripe pods on the same plant.

In Minnesota, seed production has been more successful on sandy soils which have been droughty and produced less vegetative growth.

Cross pollination is essential to good seed production. Both honeybees and wildbees work the small pealike flower with ease.

Seed is harvested when the majority of seed pods have turned brown.

Some seed is lost by shattering when harvested under field conditions. Mowing with a windrower attachment and threshing with a combine, or baling and threshing later, have been the most successful seed-harvest methods.

Insects commonly found on clovers and alfalfa are also found on trefoil. The extent of injury from serious infestations has not been evaluated to date.

Birdsfoot trefoil is subject to Rhizoctonia and Sclerotina, stem and crown rots, which may occur under conditions of very heavy growth and high humidity, but when it is grazed, these diseases do very little damage. As a group, the imported European strains of birdsfoot trefoil have been more susceptible to such diseases as crown rots than have the New York strains, such as Empire.

In general, birdsfoot trefoil has much to offer as a perennial legume for permanent sods over a wide variety of soil types which may not be suitable for general cropping practices. At present, trefoil does not replace any of our common legumes, but instead, it supplements them by providing a perennial legume capable of producing a better quality forage on poor lands which may be marginal or submarginal for normal cropping operations.

NOTES —

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